Single-Level Fusion Does Not Affect Cervical Spine Segmental Percentage Contributions to Head Rotation During Flexion-Extension

+1Anderst, W; 1Schaefman, M; 1Donaldson, W; 1Lee, J; 1Kang, J
+1Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, PA
anderst@pitt.edu

Introduction
The substantial among-subject variability in cervical motion segment range of motion (ROM) during flexion-extension makes it difficult to reliably identify abnormal motion that may occur after surgical interventions such as fusion or discectomy. Therefore, it has been suggested that within-subject analysis of the contribution to total motion made by each functional spinal unit may be more sensitive than the conventional between-subjects approach for defining segmental mobility disorders. Additionally, spinal motion should be characterized during dynamic, functional loading because static images collected at the end range of motion may not reveal movement abnormalities that lead to pain and degeneration.

The aims of this study were first, to establish normative segmental contributions to head rotation during flexion-extension in asymptomatic controls, and second, to compare these values with corresponding segmental contributions in single-level anterior fusion patients. It was hypothesized that motion segments adjacent to the fusion would exhibit increased contributions to head rotation near the end of flexion and extension.

Methods
Ten single-level anterior fusion patients (6 C56 and 4 C67 fusions; 47±13 yrs; 3 M, 7 F; 7±1 mo. post surgery; 5 allograft; 5 autograft) and 13 age-matched asymptomatic controls (46±7 yrs; 6 M, 7 F) consented to participate in this IRB-approved protocol. Subjects performed continuous, full ROM flexion-extension at a rate of one complete cycle every 3 seconds. Biplane x-rays were collected at 30 images per second for 3 seconds each dynamic trial. Two to 3 trials were collected per subject, providing 59 dynamic movement trials for analysis. Subject-specific bone models of C2-C7 were created from CT scans. A previously validated tracking process determined three-dimensional vertebral position with sub-millimeter accuracy by matching bone models from the CT scan to the biplane X-rays. Intervertebral flexion-extension rotation was calculated in each frame using bone-specific anatomic coordinate systems. Head movement was tracked at 60 Hz using reflective markers (Vicon MXF20) and expressed relative to C7 after co-registering the two tracking systems.

The contribution to head motion made by each cervical motion segment was determined continuously through the entire flexion-extension ROM and interpolated every 5% of head rotation for statistical analysis. Rotation of the head relative to C7 not accounted for by rotations of C2 through C6 was attributed to head/C2 rotation. A two-way repeated measures analysis of variance ( vertebral level by percent of total head rotation) was performed to identify significant differences in contribution to head motion within motion segments and to identify differences in contribution among motion segments at each 5% interval of head rotation. Analysis of variance was used to test for differences between control and fusion subjects at each level (excluding fused motion segments) for every 5% interval of head rotation. Tukey post-hoc analysis was performed with significance set at p < .05 for all tests.

Results
Overall head range of motion was 88±10° for the controls and 79±14° for the fusion patients (p = .065). The average difference between flexion and extension percentage contributions at every 5% of head motion was -0.4±1.3°. Therefore, flexion and extension movements were combined for analysis. Control Subjects: Motion segments increased their contributions in a superior to inferior sequence with C3/C4, C4/C5, C5/C6 and C6/C7 significantly increasing their contribution at 35%, 45%, 55%, and 90% of head rotation, respectively (Figure 1). C2/C3 and C3/C4 contributions peaked prior to the end of the range of motion. C2/C3 contribution was significantly less than C3/4 and C4/C5 throughout the entire motion, and C2/C3 was significantly less than C5/C6 near the end ranges of motion. C6/C7 contribution was less than C3/C4 and C4/C5 in the midrange (40% to 75%) of head motion. Fusion Subjects: Cervical motion segment contributions to head rotation in C56 and C67 fusion subjects were not significantly different from controls at any percent of head rotation at any non-fused segment. The average difference between control and fusion cervical motion segment percent contribution was 1.0±1.4%, with the average 95% confidence interval of the difference being -3.7% to +5.7%.

Discussion
Cervical motion segments significantly increase their contribution to head rotation in a superior to inferior sequence in flexion and in extension in controls and fusion patients. Previous reports suggested this sequential ordering may occur in flexion, but not extension. The hypothesis that motion segments adjacent to the fusion would exhibit increased contributions to head rotation near the end of flexion and extension was not supported. The close agreement between control and fusion percent contribution at every level, in addition to the narrow 95% confidence interval associated with the differences between fusion and control motion segments, strongly suggests segmental contributions to rotation are not affected by single-level fusion. This finding corresponds well to clinical studies that indicate motion loss associated with fusion does not affect clinical results, but is contrary to cadaver studies that suggest fusion negatively affects adjacent segment mechanics. Longer-term follow-up will be necessary to confirm this result.

Significance
This is the first study to characterize cervical motion segment percent contributions to head flexion-extension rotation during in vivo functional motion in asymptomatic controls and fusion patients. Single-level anterior fusion does not appear to alter the timing, sequencing, or magnitude of the percent contributions to flexion-extension, suggesting that single-level cervical fusion does not preferentially alter adjacent segment motion.


![Figure 1](https://example.com/figure1.png) % Contributing to Head Rotation by Cervical Motion Segments

Figure 1: Percent contributions to head flexion-extension rotation. Vertebral contributions remained steady the initial 30% of head movement, then increased sequentially superior to inferior. Brighter outlined bars indicate significantly larger contributions for each motion segment (p < .05).